International Journal of Fauna and Biological Studies
Available online at www.faunajournal.com

IJFBS

International Journal of Fauna And Biological Studies

E-ISSN 2347-2677
P-ISSN 2394-0522
www.faunajournal.com
IJFBS 2022; 9(1): 01-08
Received: 15-10-2021
Accepted: 02-12-2021

Kuenzang Dorji
Conservation and Environmental Research, Nature Study Center, Ugyen Wangchuck Institute for, Ugyen Wangchuck, Bhutan

Lori K Sheeran
Department of Anthropology & Museum Studies, Central Washington University, Ellensburg, WA, United States

Jigme Wangchuk
Center for Water, Climate and Environmental Policy, Ugyen Wangchuck Institute for Conservation and Environmental Research, Ugyen Wangchuck, Bhutan

Om Katel
College of Natural Resources, Royal University of Bhutan, Bhutan

Namgay Pem Dorji
Department of Environmental and Life Sciences, Sherubtse College, Royal University of Bhutan

Shacha Dorji
Ugyen Wangchuck Institute for Conservation and Environmental Research, Lamai Gompa, Bumthang, Bhutan

Corresponding Author:
Kuenzang Dorji
Conservation and Environmental Research, Nature Study Center, Ugyen Wangchuck Institute for, Ugyen Wangchuck, Bhutan

Small mammal communities of Gangtey-Phobji Ramsar Site (2264), a Wetland of International Importance, Bhutan

Kuenzang Dorji, Lori K Sheeran, Jigme Wangchuk, Om Katel, Namgay Pem Dorji and Shacha Dorji

DOI: https://doi.org/10.22271/23940522.2022.v9.i1a.867

Abstract
Small mammals support the ecological integrity of wetlands, and data on their diversity, richness, abundance, habitat use, and anthropogenic threats are essential for conservation management of wetland ecosystems. We assessed four different habitat types (forest, agriculture farm, grassland, and riparian) in Gantey-Phobji Ramsar site, Bhutan. We used Sherman and pitfall traps to capture and recapture animals, and we confirmed species based on morphometric measurements. We recorded environmental variables and anthropogenic activities that might alter small mammal presence, abundance, and diversity. We recorded 7 species and 128 individuals, as new record for the Ramsar site. Agricultural land has the highest species richness, and the forest had the highest diversity of small mammals. Small mammals used agricultural land as macrohabitat and shrubs as microhabitat. Small mammal occurrence varied in each habitat we sampled; therefore, holistic conservation interventions specific to habitat type are essential to conserve both wetlands and small mammals.

Keywords: Bhutan, conservation, Ramsar site, high altitude, small mammals, wetland

Introduction
Small mammals refer to species weighing less than 500 g, the upper size limit that can easily be caught in commercially produced live traps [19]. Some studies in South Africa reserved the term “small mammals” for mammals weighing less than some arbitrary threshold (e.g., 2 kg or 5 kg) and limited to rodents, shrews, and bats [44]. Small mammals can be terrestrial or volant in nature and are smaller than the largest rodents or lagomorphs. Shrews, moles, mice, voles, gophers, and ground squirrels are some of the more commonly observed terrestrial small mammals [4]. Small mammals have significant influences on vegetation and soils, exert predatory pressure on other animals, and provide food for predators [41]. They can indicate the health and state of wetlands due to their rapid turnover rate, high biotic potential, ability to invade reclaimed areas, and sensitivity to environmental disturbance [18]. Wetlands provide habitat for diverse wildlife [1] and varied benefits to people such as flood abatement, erosion control, habitat enhancement, and cultural services [13]. Wetlands support small mammal communities and are areas of conservation importance [7]. The conservation of small mammals is as critical as that of large mammals because small mammals form the prey base for many avian and mammal predators in ecosystem [46].

Among all mammals, small mammals have the highest species diversity, and are comprised of 3,821 species most often spanning the orders Rodentia (rodents), Chiroptera (bats), and Soricomorpha (shrews) [19], but they are also found in lower numbers in other orders. South Asia has recorded 332 species of small mammals classified in the orders Rodentia, Chiroptera, Soricomorpha, Erinaceomorpha (hedgehogs), Lagomorpha (pikas and hares), Scandentia (tree shrews), and Pholidota (pangolins) in South Asia [43]. Currently, India has 103 species and 89 subspecies of small mammals classified in 46 genera, representing 66% of Indian mammal records [33].

Data on small mammals in Bhutan are scant [37], but there was a record of 44 species, constituting 20% of the country’s mammal records [47]. The study in Jigme Dorji National Park (JDNP), recorded six species of rodents which was new record to that particular park [14]. Similarly, four species of small mammals were recorded in Royal Manas National Park, south central Bhutan [42] and 15 species of small mammals from Bumdeling Ramsar site in northeastern Bhutan [34].

Although conservation of small mammals is essential to ecosystem health, to date no studies have occurred to understand their diversity and population status in Bhutan [45]. Due to this lack of vital information on their distribution, abundance, population trends, and conservation status, small mammals are not yet included in any of Bhutan's environmental legislation and policies [14].

Small mammals are vital components of wetland ecosystems [7]. Gangtey-Phobji Ramsar in Bhutan's central highlands (hereafter, Ramsar) provides wintering habitat for the endangered black-necked crane [38] and other associated wildlife species. The Ramsar site totals 970 km^2 and is one of the largest high altitude wetlands in Bhutan [27]. The site has four habitat types: forest, grassland, freshwater, and agricultural, which is home to 25 mammal species and 90 bird species [39]. The government's strategic plan to conserve the Ramsar site was developed using ecological principles, the planners lacked information on the site's small mammals. There is a need to document the diversity of small mammals at the site in relation to the four habitat types and to assess conservation threats to small mammal species in Ramsar site.

Our goal was to address this gap in our knowledge of Bhutan's biodiversity at Ramsar site, specifically to: (1) estimate the species diversity and relative abundance of terrestrial small mammals with relation to habitat types; (2) assess the effect of environmental variables on presence of small mammals; and (3) identify the conservation threats that affect the survival of small mammals. We hypothesized that forest habitat would support higher small mammal diversity than does agricultural land, riparian and open-grass land habitats. Our results will provide information needed to generate holistic conservation interventions for the Ramsar site and may provide a model for small mammals living in different habitats where there are different land uses.

Materials and Methods

We collected data on small mammal communities from Gantey-Phobjikha Ramsar site, from December 2015-June 2016 (Figure 1). We collected data from four habitat types, *viz*. 1. forest, 2. open grass (pasture, shrubs, and meadows), 3. agricultural field (agriculture land and settlements), and 4. riparian (water bodies, marsh) that totals 162 km^2 (Table 1)

Table 1: Area of land under major habitat types

Habitat Types	Area (km²)
Forest	101.67
Open Grass Land	45.4
Agricultural Land	9.44
Riparian	5.49
Total	162

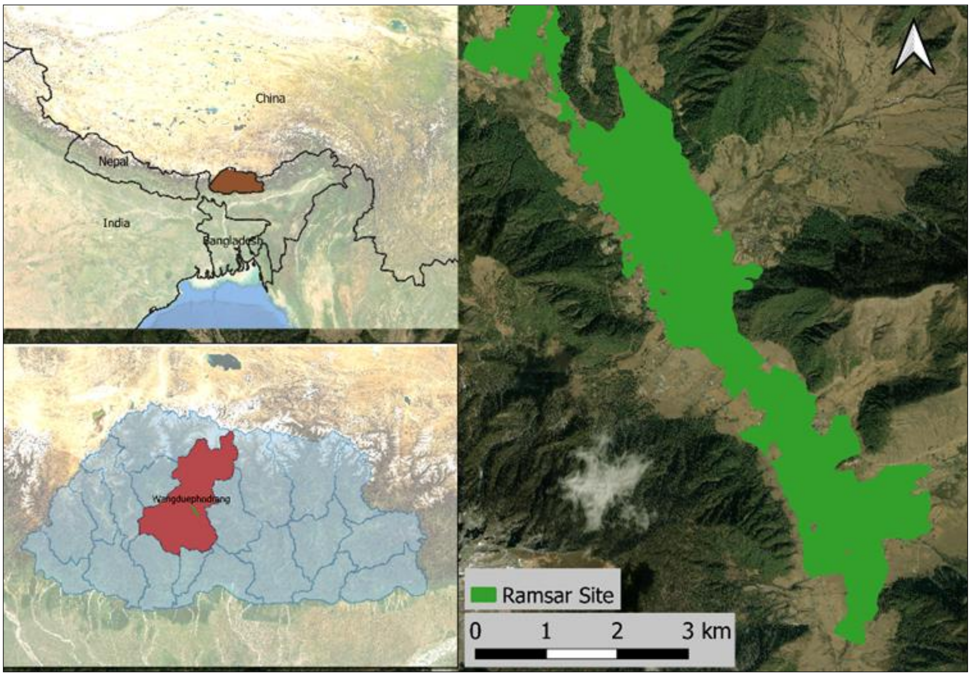

Fig 1: Location of Gangtey-Phobjikha Ramsar site, Western Bhutan

We have used transects as they are reported to yield greater numbers of captures, individuals captured, and species captured [15] and while enabling the sampling of a larger area [35]. The transect lines can be straight or meandering [36], and the spacing between traps ranged from 10-25 m. We laid straight transects in terrestrial habitats (forests, agriculture, and open grass land) and meandering transects in the riparian habitat. We used Sherman live traps as they capture the most animals and appear to be the most effective traps for capturing small-sized mammals [19]. We laid four 300 m length transects in four different habitats (forest, agriculture land, open area and riparian). We set 20 Sherman live traps of size 23 x 9 x 8cm on the ground at approximately 15 m intervals to capture mouse/rat/squirrel sized animals. We tied colored ribbon (red, orange, pink and blue) on twigs and branches of shrubs for ease in locating the traps. We baited the traps with a mixture of oats, apple, peanut butter, and puffed rice.

We placed the Sherman traps under vegetative cover or near rocks, tree bases, or coarse woody debris similar to the study conducted to examine the responses of small mammals to wildfire in mixed conifer forest [5]. We covered the traps with leaves or litter for camouflage [32] and placed cotton batting, pine needles, *Pteridum sp*, dry grasses, and old and torn clothes at the back of each trap for insulation [5].

Pitfall traps have been found to generate higher estimates of small mammals [6], and the use of pitfall traps at minimum of

60 m spacing is suggested to capture smaller-bodied species like shrews [36]. We set six pitfall traps at every 60 m intervals to capture shrews in traps baited with a mixture of flour, canned fish, and, for moisture to increase animal survival, sliced carrots. The traps were cleaned after each trapping session to increase consistency in trapping success [21]. We soaked the traps in water for ≥ 12 hours and cleaned each before moving the traps to a new location.
The transect lengths were 300m long, and we trapped on 3-5 consecutive nights depending on habitat type and time available [2,40] determined the minimum number of traps nights by plotting species accumulation curves from different numbers of trap nights and found that three trap nights revealed the same species as six. All of our trapping was conducted within 60 days in order to sample a closed population and avoid periods of high immigration [9]. We checked traps in the morning from 0600-1000 h and in late afternoon from 1500-1800 h to document capture of both diurnal and nocturnal small mammal [25]. We re-baited he traps for next consecutive trap nights in each habitat.
We used the biodiversity calculator to calculate Shannon Diversity Index (H') and Evenness (J) for seven species of small mammals in each of the four habitats. We used the calculated indices to compare species diversity in each of the four habitat types. Species richness (s) for each habitat types was calculated using the formula, R = S-1/LogN, where R = species richness index, S = total number of species, and N = total number of individuals of all the species in a given area (adopted from Kohli *et al*., nd).
We estimated trapping success (*Ts*) as the total number of captures per 100 trap-nights (one trap night = one trap set for one night):

$$Ts = \frac{Tc \times 100}{Tn}$$

Where
Tc = total number of captures at a site
Tn = total number of trap nights at a site
We estimated the relative abundance of the i^{th} species as the percentage abundance of this species in the total number of captured individuals of all species at a site:

$$Ar = \frac{N_i \times 100}{Tc}$$

Where
Tc = total number of captures at a site
Ni = total number of individuals of the species captured at a site.

We used Statistical Package for Social Sciences (SPSS) version 21.0 to analyze and assess the effect of environmental variables on the presence of small mammals. We used one sample t- tests to compare the mean body and tail length of species captured in this study with test values of same species in Jigme Dorji National Park. We used chi-square tests of independence to analyze the relationship between the slope gradient and ground cover. We used Spearman's Linear Regression test to study the relationship between the number of small mammals and microhabitat features (e.g., presence of shrubs, grass, and piled stones) and cross tabulation to better understand the macro- and microhabitat use of small mammals.

Results

Species Composition, diversity, richness, and evenness of small mammals

We recorded and identified a total of 128 small mammals during 960 trap nights (16 transects X 20 traps per transect), belonging to 7 species, mostly Rodentia (5 species [*Niviventer eha*, *N. niviventer*, *Rattus rattus*, *Macrotus sikimensi*s, and *Dremomys lokriah*] and 48 individuals), 1 species (*Sorex sorex*) of Insectivora (79 individuals), and 1 species (*Ochotona macrotis*) of Lagomorpha (1 individual). The numbers of animal trapped in each habitat type was forest 28.1% (n=36); agricultural land 57% (*n*=73*);* riparian 14% (*n*=18), and open grass land 1% (n=1) (Table 2). The number of small mammals captured in the forest habitat ranged from 4 in *Juniperus recurva* and *Abies densa* mixed forest; 7 in *Tsuga Dumosa* forest, and 27 in blue pine (*Pinus walliciana*) dominated forest. The species richness was higher in the agricultural habitat (*R* = 6.46) followed by forest (*R* = 6.36) and riparian (*R* = 6.20) habitats and was lowest in open grass land habitat (*R* = 0). The forest habitat also had the high diversity of the small mammals (H' = 0.53) with six species; we found an intermediate diversity in agricultural habitat (H' = 0.42) with four species, and low diversity in open grass land habitat (H'= 0.00) with only one species recorded (Figure 2).
At the species level, relative abundance varied between different species of small mammals. *Sorex minutus* (*Ar* = 0.62) appeared to be highly abundant and widespread in three habitat types with the exception of grassland. We captured *Niviventer niviventer* (*Ar* = 0.20) in three habitats, but not in riparian habitat. *Ochotona macrotis* and *Niviventer eha* (*Ar*= 0.01) had relatively low abundance scores and were associated with forest habitat. *Rattus rattus* (*Ar*= 0.02) was captured from agricultural field, and one individual has been captured from riparian habitat which was close to settlements and agricultural field. The most unusual capture was that of two *Dremomys lokriah* (*Ar*= 0.02), habitually an arboreal species and consequently unlikely to be captured in Sherman traps (Table 2).

Table 2: Composition of species in the forest, agricultural, riparian and grassland habitats (Gangtey-Phobji Ramsar Site. Data from 960 trap nights, 240 trap-nights in each habitat types

Scientific Names	Common Names	Habitat Types			
		FOR	AGL	RPN	OGL
Sorex sorex	Pygmy Shrew	*	*	*	
Niviventer niviventer	Himalaya White Bellied Rat	*	*		*
Ochotona macrotis	Large-eared pika	*			
Dremomys lokriah	Orange-bellied Himalayan Squirrel	*			
Neodon sikimensis	Mountain sikkim vole	*	*	*	
Rattus rattus	Common house rat	*			
Niviventer eha	Little Himalayan rat		*	*	

*Note: FOR=Forests; AGL=Agricultural land; RPN=Riparian; and OGL=Open grass land

Table 3: The species diversity and relative abundance of small mammals in forest, agricultural, riparian, and grassland habitats. Data from the 960 trap nights, 240 trap-nights in each habitat

Species	Number of Individual (n)	%	Relative Abundance (p_i)	ln p_i	p_i (ln p_i)
Sorex minutus	79	61.72	0.62	-0.20958	-0.12935
Niviventer niviventer	26	20.31	0.20	-0.69224	-0.14061
Ochotona macrotis	1	0.78	0.01	-2.10721	-0.01646
Dremomys lokriah	2	1.56	0.02	-1.80618	-0.02822
Macrotus sikimensis	17	13.28	0.13	-0.87676	-0.11644
Rattus Rattus	2	1.56	0.02	-1.80618	-0.02822
Niviventer eha	1	0.78	0.01	-2.10721	-0.01646
Total	128	100.00	1.00	9.60536	0.475776

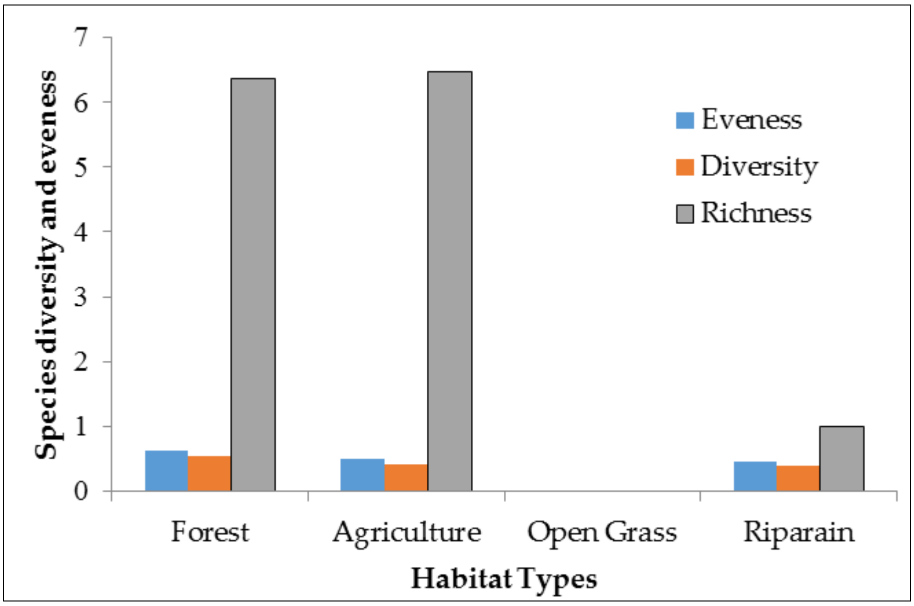

Fig 2: Species Diversity, Evenness and Richness of three orders (Insectivora, Lagamorpha and Rodentia) of small mammals in four habitat types.

Number of small mammals in relation to aspect and slope

The maximum slope gradient of forest, agricultural, grassland, and riparian habitats were 45%, 15%, 25%, and 10% respectively. The number of animals recorded were 84% (n=107) on gentle slope (0-15%), 14% (*n*=19) on moderate slope (16-30%), and 2 % (*n*=2) on steep slope (31% and above). The largest number of animals were recorded on gentle slope 84% (n=107) (Table 3).

Table 3: Number of small mammals in different slopes in percent

	Slope Category			
	Gentle (0°-15°)	Moderate (16°-30°)	Steep (31° and above)	Total
Insectivora	66	12	1	79
Lagomorpha	1	0	0	1
Rodents	42	5	1	48
Total	109	19	2	128
Percent	85.16%	14.84%	1.56%	

Likewise, small mammals responded to habitat aspect. We found 39.06% (n=50) of the animals at northeast aspect; 21.09% (n=27) southeast, 13.28% (n=17) south, and 10.16% (n=13) east (Figure 3)

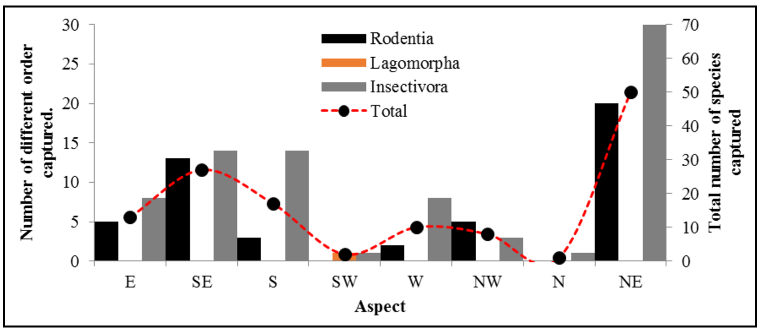

Fig 3: Aspect preferred by different orders of small mammals

Macro- and Microhabitat use by small mammals

Microhabitats include grass, shrubs, piled stones, and felled logs, and these might occur in different combinations in each of the four habitats. The grass microhabitat consisted of both herbaceous plants and grasses like *Pteridum* species and *Artemisia spp*. Shrubs included *Yushina Macrophylla*, *Rosa sericea*, *Rhododendron spp*, *Sarcococca spp*, *Cotoneaster microphyllus*, *Berberis wallichiana*, and *Berberis angulosa*. Of 128 individuals, 55.5% (*N*=71) were captured under shrubs, 24.2% (*N=31*) under piled stone, 17. 2% (*N*=22) in grass, and 3.1% (*N=4*) under felled logs.

We cross tabulated order of small mammals and microhabitat type to find that 60.56% (N=43) of Insectivora, 38.02% (N=27) of Rodentia, and 1.40% (N=1) of Lamorpha inhabited shrub microhabitat (Table 4). The chi-square test result showed that small mammals were significantly more likely to be found in agricultural habitat (χ^2 (18) = 22.26, *p* = .22) (Annexure V) and in shrub microhabitat (χ^2 (18) = 40.44, p =.002).

Table 4: Order and microhabitat cross tabulation

		Microhabitat				
		Grass	Shrubs	Piled Stones	Down Log	Total
Order	Insectivora	16 (73%)	43 (61%)	18 (58%)	2 (50%)	79
	Rodentia	6 (27%)	27 (38%)	13 (42%)	2 (50%)	48
	Lagamorpha	0 (0%)	1 (1%)	0 (0%)	0 (0%)	1
Total		22	71	31	4	128

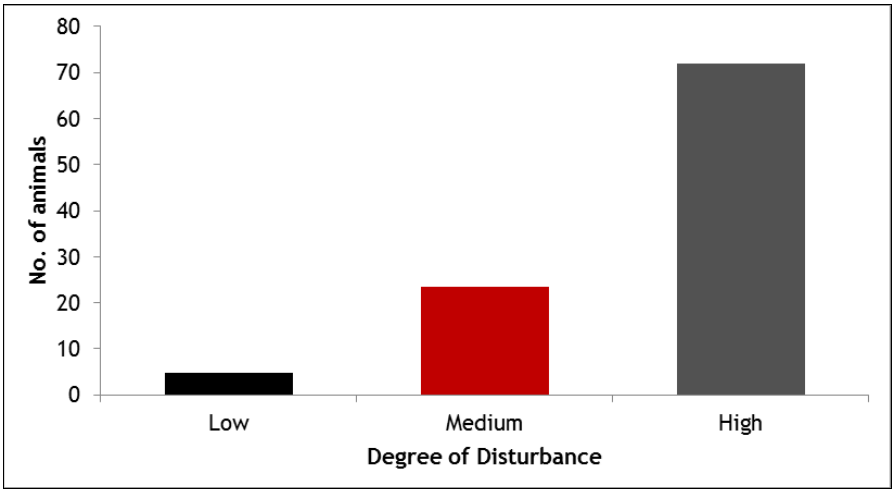

Fig 4: The degree of disturbance in 128 trapping sites of forest, agricultural, grassland, and riparian habitats.

Conservation threats

We observed signs of domestic cattle grazing in all trapping locations (N=55), 33% of sites were near roads (N=18), 65% of sites showed signs of timber extraction (N=36), and 7.27% of sites showed evidence of stone quarrying (N=4). Notably, we observed no incidence of fire. Out of 128 capture sites, 72% (n = 92) had high intensity disturbances, 23% (n = 30) had medium intensity disturbances, and 5% (n = 6) had low intensity disturbances (Figure 4). Of 128 the individuals captured, we recorded 72% (*n*=92) from highly disturbed areas particularly from agricultural and forest habitats in which soil was disturbed due to road construction and free plying of machineries like tractor. We found a positive monotonic relationship between the degree of disturbance and species presence (r_s= .114, p > .236, df)

Discussion

The presence of high species richness in forest and agricultural land was due to availability food. The results substantiated the findings which stated that small mammals select habitats that offer food and anti-predatory refuges [31]. This shows that small mammal diversity may be altered according to different habitat types. The species diversity of small mammals was high in forest habitat due to more coverage for protection, resources, and safe areas [26]. Further, our findings supported strong positive relationship between plant richness and small mammal species [22,23]. At the species level, the relative abundance varies between different species of small mammals. Similarly, at the habitat level, the relative abundance of small mammals varied between habitat types. The agricultural field fenced with piled stone and growing crops and other crop residues provided food and shelter to small mammals. Therefore, the relative abundance of small mammals in agricultural land is comparatively higher when compared to forest, riparian, and open grass land. Generally, the low abundance and diversity of small mammals in open grass land could be due to disturbance and absence of sheltering habitat.

The number of small mammals captured indicated that they usually prefer flat areas with gentle slopes of gradients of 0-15%. Species number gradually decreased with the increased slope gradient. All of the small mammals captured on gentle slopes are terrestrial in nature. However, lower capture of *Niviventer niviventer* contradicts with the result of studies conducted in JDNP [14] wherein this species was captured within the slope range of 20-50%. The capture of two individuals of *Dremomys lokriah* on intermediate and steep slope of forest habitat substantiates that particular species is arboreal in nature and inhabits steeper slope. The slope, aspect, and elevation affects the richness and abundance of small mammals [5], and the slope influences local climate, especially solar radiation and exposure to wind [48]. Gentle slopes in forest habitat might accumulate leaf litter along with the presence of logs and shrubs for protection. Agriculture farming is also usually practiced on gentle slope. In addition, the general slope gradient of the valley is gentle and most of the transects we deployed for trapping ran over flat and gentle slopes.

Sorex minutus is generalist species and occurred in our dataset in all slope classes indicative of its broad ecological niche. We also captured one individual of *Sorex minutus* on steeper slope. The absence of other species of small mammals on steep slopes could be due to our more limited number of samples, which might have reduced the detection probability of other small mammals. Our detection probability might also have changed if animals were trapped during different seasons. Since there was no significant relationship between ground cover percentage and the slope gradient (r_s = .114, p>.01), the abundance of small mammals does occur irrespective of slope. The aspect of the habitat influences the use of a habitat by small mammals. Small mammals appear to prefer mostly east and south facing aspect, and they seem to avoid north and southwest aspect. However, the only individual of Lagomorpha order we captured was in southwest aspect which indicates that different species might prefer different slope and aspect. The other two orders (Insectivora and Rodentia) were more often found in northeast followed by southeast aspects. Our analysis of the number of species shows that insectivores were captured in all aspects but with higher numbers at northeast, southeast, and south aspects.

Microhabitat features include aspects of the environment that influence food availability, predation risk, temperature, and lunar phase [30], and each animal species selects specific microhabitats for protection, foraging, or micro-climate [29]. In our dataset, we noted stone piled around agricultural habitat and felled logs included the uprooted trees and rotted tree stumps in all four habitats. Microhabitat are comprised of different plant species and have different ground cover, so the numbers of captured animals are likely to vary with microhabitat types. Nonetheless, the assessment of microhabitat preference by small mammals in this study may not be reliable, as we placed the traps subjectively to increase the capture rate and the numbers of samples for each microhabitat were not equal. Most of the animals we captured were in shrub, piled stone, and felled log microhabitats. Furthermore, our capture rate varied between four macro habitats. In the agricultural habitat, mainly piled stone made microhabitat features, while shrubs and grasses were the main microhabitat features in forest habitat. Consequently, microhabitat structure differed between habitats.

In general, we found small mammals mostly in shrubs when compared to the other three microhabitats (grass, piled stone, and felled logs). Most small mammals live under shrubs, which are perennial and evergreen and provide safe protection and foraging in all seasons. Likewise, at the order and species levels of small mammals, most of the animals we captured were from sites with shrub microhabitats. The past study conducted in Jigme Dorji National Park confirmed that *Yushina macrophylla* and *Rosa spp* associated with other tree species were habitats use by small mammals [14]. The percent cover of herbs, grasses, and shrubs as well as felled logs explained the variation of microhabitat components among all major habitat types. To describe the relationship between the number of small mammals and microhabitat use, variables such as canopy cover, shrub cover, and ground cover have been used. Many studies on microhabitat use show that certain microhabitat components may provide particular functions that attract small mammals [8]. Past studies reported preference for certain microhabitat components that exists among generalist species [12]. The result generated from our study show that the small mammals captured were significantly influenced by microhabitat. It has been reported that the dense ground cover is the most important microhabitat feature, presumably because it provides both food and shelter [24].

Threats to small mammals could be natural and/or anthropogenic. We assessed anthropogenic threats in forest, riparian, and grassland habitats; we excluded the agricultural habitat from this analysis. Given that local peoples' livelihoods at Ramsar site are mainly agriculture and animal husbandry [39], it is not surprising that we observed grazing in all trapping locations. Timber extraction accounted for 65.45% of threat, mainly due to easy road access into forest. This was because of the flat and gentle slope of valley, which made it easy for tractors to move into the area even without proper road construction. Small mammals (especially habitat-specialist species) are threatened with extinction due to habitat loss and defragmentation, deforestation, the use of insecticide, and roost disturbance [16]. Some literature mentioned scanty information available on small mammals, which further complicates conservation efforts on their behalf [10]. In Bhutan, small mammal populations are impacted by logging, grazing, forest fires, urbanization, and infrastructure development [37]. The similar study in Jigme Dorji National Park [13] listed six types of conservation threats that included farm road construction, cattle grazing, firewood collection, stone collection, feral dog predation, and timber extraction [14]. We classified anthropogenic threats into low, medium, and high intensities to study the response of small mammals to disturbance intensities. We recorded a high number of individuals from highly disturbed areas particularly from agricultural and forest habitats in locations where soil was disturbed due to road construction and free plying of machineries like tractors. Our finding supports the findings of past studies [17], who stated that small mammals were highly responsive to environmental disturbance and invade reclaimed areas.

Conclusions

We found that species diversity and relative abundance of small mammals were comparatively high in agricultural and forest habitats. The number of small mammals was related to habitat type, slope gradient, aspect, and microhabitats. Gentle slopes and east facing aspect were mostly used by small mammals. The presence of small mammals was positively associated with microhabitats. Small mammal presence was greater in microhabitats with shrubs and piled stones. The cover and availability of food in the habitat also influences the presence of small mammals.

Likewise, small mammals positively responded to anthropogenic disturbances. We recorded the largest number of small mammals from sites where the degree of disturbance was high mainly due to grazing, timber extraction, and road construction. The overall degree of disturbance in study area was high. Due to small mammals' responsiveness to environmental disturbance and ability to invade reclaim areas, we captured large numbers of small mammals from disturbed areas. Nevertheless, it is difficult to conclude that small mammals responded to anthropogenic disturbance as the animal recorded from agricultural land was also included for data analysis.

The occurrence of small mammals was high mostly in habitat that had good cover, gentle-east facing slope, and high intensity of disturbance. In principle, wetland conservation is supported by conservation of small mammals. Thus, understanding species diversity is the key ecological variable to be considered for holistic and comprehensive planning for small mammal species as well as high altitude wetland conservation.

A limitation of our study is that we collected data only during the winter season, and data collected during winter months may not be enough to generalize the species diversity across all seasons. A future study spanning all seasons is recommended to generate a comprehensive list of small mammals of Ramsar site. Unplanned extraction of timber and use of tractors inside the forest habitat should be strictly monitored through establishment of community forest.

Acknowledgements

This research was supported by Royal Society for Protection and Nature (RSPN) Bhutan and Rufford Foundation. My special thanks to Mr. Rinchen Dorji, Jigme Singye Wangchuk National Park, Mr. Sonam Choenjur, Lochina Lower Secondary School and Mrs. Kuenzang Choden, Help Tourism Bhutan for helping me throughout the data collection period.

References

1. Anderson JT, Davis CA. (Eds.). Wetland Techniques: Volume 3: Applications and Management. Springer Science & Business Media. 2013, 3.
2. Attuquayefio DK, Ryan JM. Taxonomic report on small mammals from two coastal wetland (Ramsar) sites in Ghana. West African Journal of Applied Ecology. 2006, 10(1).
3. Baker MAA, Brown JS. Foraging in space and time structure an African small mammal community. Oecologia. 2014;175(2):521-535.
4. Barnett A. Expedition field techniques: small mammals *(excluding bats)*. Expedition Advisory Centre. 1992.
5. Borchert MI, Farr DP, Rimbenieks-Negrete MA, Pawlowski MN. Responses of small mammals to wildfire in a mixed conifer forest in the San Bernardino Mountains, California. Bulletin, Southern California Academy of Sciences. 2014;113(2):81-95.
6. Bovendorp RS, Mccleery RA, Galetti M. Optimising sampling methods for small mammal communities in Neotropical rainforests. Mammal Review. 2017;47(2):148-158.
7. Bowland JM, Perrin MR. Wetlands as reservoirs of small-mammal populations in the Natal Drakensberg. South African Journal of Wildlife Research-24-month delayed open access. 1993;23(2):39-43.
8. Bowman JC, Sleep D, Forbes GJ, Edwards M. The association of small mammals with coarse woody debris at log and stand scales. Forest Ecology and Management. 2000;129(1-3):119-124.
9. Carey AB, Johnson ML. Small mammals in managed, naturally young, and old-growth forests. Ecological applications 1995;5(2):336-352.
10. Chandrasekar-Rao A. Distribution and ecology of Hong Kong small mammals, with special reference to seasonality. *香港大學學位論文*, 1-0. 1994.
11. Chernousova NF. Population dynamics of small mammal species in urbanized areas. Contemporary problems of ecology. 2010;3(1):108-113.
12. Chupp AD. Habitat selection in four sympatric small mammal species and the effects of potential predators on Peromyscus leucopus. (Issue August). Virginia Commonwealth University. 2005.
13. De Groot D, Brander L, Finlayson C. Wetland ecosystem services. In The wetland book I: Structure and function, management and methods. Springer. 2018, 323-333.
14. Dorji J. Species diversity and distribution of rodents along the elevational gradients in Jigme Dorji National Park. College of Natural Resources, Lobesa, Bhutan. 2013.
15. Fricke KA, Kempema SL, Powell LA. Ecology of small mammals, vegetation, and avian nest survival on private rangelands in Nebraska. Great Plains Research. 2009, 65-72.
16. Friedmann Y, Daly B. Red data book of the mammals of South Africa: a conservation assessment. *CBSG Southern Africa, Conservation Breeding Specialist Group (SSC/IUCN)*, Endangered Wildlife Trust, South Africa, 2004, 147-149.
17. Garshong RA, Attuquayefio DK, Holbech LH, Adomako JK. Distribution and abundance of small mammals in different habitat types in the Owabi Wildlife Sanctuary, Ghana. Journal of Ecology and the Natural Environment. 2013;5(5):83-87.
18. Griffen BD, Spooner D, Spivak AC, Kramer AM, Santoro AE, Kelly NE. Moving species redundancy toward a more predictive framework. In Eco-DAS VIII Symposium Proceedings. ASLO. 2010, 30-46.
19. Hoffmann A, Decher J, Rovero F, Schaer J, Voigt C, Wibbelt G. Field methods and techniques for monitoring mammals. Manual on field recording techniques and protocols for all taxa biodiversity inventories. 2010;8(part 2):482-529.
20. ICIMOD; RSPN. An integrated assessment of the effects of natural and human disturbances on a wetland ecosystem: A retrospective from Phobjikha Conservation Area, Bhutan. Kathmandu: ICIMOD. 2014.
21. Jones C, McShea WJ, Conroy MJ, Kunz TH. Capturing mammals. Measuring and monitoring biological diversity: standard methods for mammals. 1996, 115-155.
22. Keller C. Do small mammals affect plant diversity? Field studies in namaqualand, South Africa, a biodiversity hotspot (Diploma thesis). Germany: University of Munster. 2005.
23. Keller C, Schradin C. Plant and small mammal richness correlate positively in a biodiversity hotspot. Biodiversity and Conservation. 2008;17(4):911-923.
24. King CM, Innes JG, Flux M, Kimberley MO, Leathwick JR, Williams DS. Distribution and abundance of small mammals in relation to habitat in Pureora Forest Park. New Zealand Journal of Ecology. 1996, 215-240.
25. Kiwia HYD. Species richness and abundance estimates of small mammals in Zaraninge coastal forest in Tanzania. Tanzania Journal of Science. 2006;32(2):51-60.
26. Kurpiewski A, Marklevits K, Treiber E. Comparison of species diversity of small mammals in forest and prairie habitats. 2010.
27. Lhamo P, Kabir A, Uddin SMN. Assessing the influence of human settlements on the plant diversity in wetlands of

Phobji and Gangtey, Bhutan. Natural Science and Technology. 2020;12:11-14
28. Meliyo JL, Kimaro DN, Msanya BM, Mulungu LS, Hieronimo P, Kihupi NI, *et al*. Predicting small mammal and flea abundance using landform and soil properties in a plague endemic area in Lushoto District, Tanzania. Tanzania journal of health research. 2014, 16(3).
29. Melo GL, Miotto B, Peres B, Caceres NC. Microhabitat of small mammals at ground and understorey levels in a deciduous, southern Atlantic Forest. Anais da Academia Brasileira de Ciências. 2013;85:727-736.
30. Mohammadi S. Microhabitat selection by small mammals. Advances in Biological Research. 2010;4(5):283-287.
31. Mugatha SM. The influence of land use patterns on diversity and abundance of rodents in Gachoka division of Mbeere district, Kenya (Doctoral dissertation). 2004.
32. Mulungu LS, Makundi RH, Massawe AW, Machang'u RS, Mbije NE. Diversity and distribution of rodent and shrew species associated with variations in altitude on Mount Kilimanjaro, Tanzania. 2008.
33. Nameer PO, Molur S, Walker S. Mammals of Western Ghats: A simplistic overview. Zoos' Print Journal. 2001;16(11):629-639.
34. Norbu L, Thinley P, Phurpa UD, Tshering P. Diversity and seasonal abundance of small mammals in Bumdeling Ramsar Site, Trashiyangtse, Eastern Bhutan. Journal of Biodiversity and Environmental Sciences. 2020;15(3):36-45.
35. Pearson DE, Ruggiero LF. Transect versus grid trapping arrangements for sampling small-mammal communities. Wildlife Society Bulletin, 2003, 454-459.
36. Resources Inventory Committee. Inventory methods for small mammals: shrews, voles, mice & rats. Standards for components of British Columbia's biodiversity, 1998, 31.
37. RGoB. Biodiversity Action Plan. National Biodiversity Centre, Ministry of Agriculture Royal Government of Bhutan, Thimphu. 2009.
38. RSPN. Phobjikha Landscape Conservation Area Management Plan. Royal Society for Protection of Nature, Thimphu, Bhutan. 2010.
39. RSPN. Study of climate change impact on wetland ecosystem Phobjikha, West Central Bhutan, Royal Society for Protection of Nature, Thimphu, Bhutan. 2014.
40. Scott DM, Joyce CB, Burnside NG. The influence of habitat and landscape on small mammals in Estonian coastal wetlands. Estonian Journal of Ecology. 2008, 57(4).
41. Sieg CH. Small mammals: pests or vital components of the ecosystem. In Great Plains Wildlife Damage Control Workshop Proceedings US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 1987, April;97:88-92.
42. Wangmo S, Wangdi Y, Wangchuk D. Report on estimating small mammal abundance in Royal Manas National Park. Research Information and Management Planning Section, Royal Manas National Park, Bhutan. 2014.
43. Srinivasulu C, Srinivasulu B. South Asian mammals: their diversity, distribution, and status. Springer Science & Business Media. 2012.
44. Taylor PJ, Rautenbach A, Schoeman MC, Combrink X. A winter survey of the smaller mammals of the uMkuze section of the iSimangaliso Wetland Park, KwaZulu-Natal Province, South Africa. Unpublished report. 2007.
45. UWICE. Procedure for Implementing Small Mammals Inventories in Bhutan. Ugyen Wangchuck Institute for Conservation and Environment, DoFPS, Bhutan. 2011.
46. Van den Bergh MB, Kappelle M. Diversity and distribution of small terrestrial rodents along a disturbance gradient in montane Costa Rica. Revista de biología tropical. 1998;46(2):331-338.
47. Wangchuk T. A field guide to the mammals of Bhutan. Mammals of Bhutan. 2004.
48. Warren K, Eppes MC, Swami S, Garbini J, Putkonen J. Automated field detection of rock fracturing, microclimate, and diurnal rock temperature and strain fields. Geoscientific Instrumentation, Methods and Data Systems. 2013;2(2):275-288.